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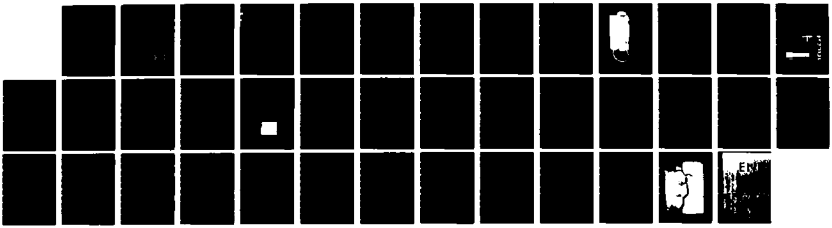

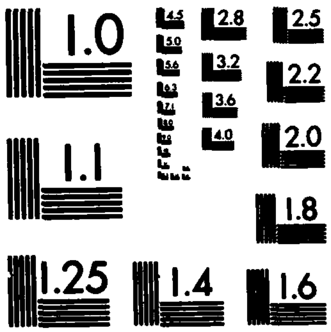
1.0
4.5
5.0
5.6
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

(12)

AFGL-TR-78-0006

PHOTOGRAPHIC MEASUREMENTS OF ELECTRICAL DISCHARGES

Equipment Information Report

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PhotoMetrics, Inc.
442 Marrett Rd., Lexington, MA 02173

15 November 1977

Scientific Report No. 1

Prepared for

AIR FORCE GEOPHYSICS LABORATORY
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Operating instructions, diagnostic procedures and theory of the circuits used in an instrument for photographic measurements of electrical discharges are presented. Schematic wiring diagrams for the intervalometer and time code circuits, the optical system for film annotation and photographs of the complete instrument are included.

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SECTION I

GENERAL DESCRIPTION

INTRODUCTION

This report provides the necessary operating and diagnostic procedures for using and maintaining the photographic system designed and developed by PhotoMetrics, Inc., to be flown as part of the payload of an Astrobee-F rocket. Its purpose is to record electrical discharges across an insulated separator ring, and between the forward rocket body and nearby atmospheric plasma during an approximately 10 min portion of the rocket's flight.

Section I contains an outline of instrument operation, descriptions of the individual components, an explanation of the digital time code, and operating instructions and procedures. Section II provides electronic circuit theory and diagnostic information, in sufficient detail for a technician to repair or replace components in the intervalometer. Photographs of the complete instrument and its printed circuit board, interconnecting diagrams, cable and pin assignments, and electrical schematics are included. Operating and maintenance instructions for the 16 mm-1VN camera itself are not reproduced here, since a manual was furnished by the manufacturer to AFGL personnel when they procured the camera and magazines. However, references to the camera manual are supplied where they clarify instrument operation. They appear as page numbers enclosed with parentheses.

OUTLINE OF OPERATION

The camera and intervalometer were designed to operate in conjunction with the electron and positive ion beam experiments onboard the Astrobee rocket. The operating parameters of the guns will be varied systematically to produce a cycle of 12 different conditions, or modes. These 12 modes, each ~ 1/2 sec long, will be repeated continuously throughout the flight under control of an onboard

programmer. By utilizing signals from this programmer, the intervalometer synchronizes the film and shutter movement with the mode changes. The camera shutter is operated in a normally-open configuration, that is, it is always open except for a brief (~1/25 sec) period when the film is being advanced. Film advance occurs at each change of the guns' mode. Thus, a separate frame of data is recorded for each of the 12 modes, and the exposure duration is equal to length of each mode.

The basis of the photographic system is the Model 16 mm-1VN camera, manufactured by Photo-Sonics, Inc., Burbank, California (p 1-2). The complete instrument consists of four individual components: 1) the 16 mm camera, which includes a motor to drive the film and shutter, 2) a detachable film magazine, 3) the taking lens and 4) an intervalometer which provides camera run signals and contains a digital display which imprints the mode and cycle numbers on the film. The housing for the intervalometer electronics and mode/cycle display is assembled with the camera and lens into a rigid unit, illustrated in Figures 1 and 2.

COMPONENTS

16 mm Camera Modifications

The shutter of the 1VN is a disk which rotates in front of the film (pp 1-6 & 3-3). It has a 120° open segment, whose angular position is sensed by an LED and phototransistor via a hole in the disk perimeter. As supplied, the shutter is normally-closed; that is, it is always closed except during the film exposure period - in this case, about 14 milliseconds per shutter rotation. We modified the camera to allow time exposures (normally-open shutter) by changing the hole location in the shutter perimeter so that the rest position of the disk opening is in front of the film aperture. Other modifications were milling a slot near the film aperture plate to install a prism, part of the mode/cycle display optics (Fig 3a), and changing the input connector to a more compact type.

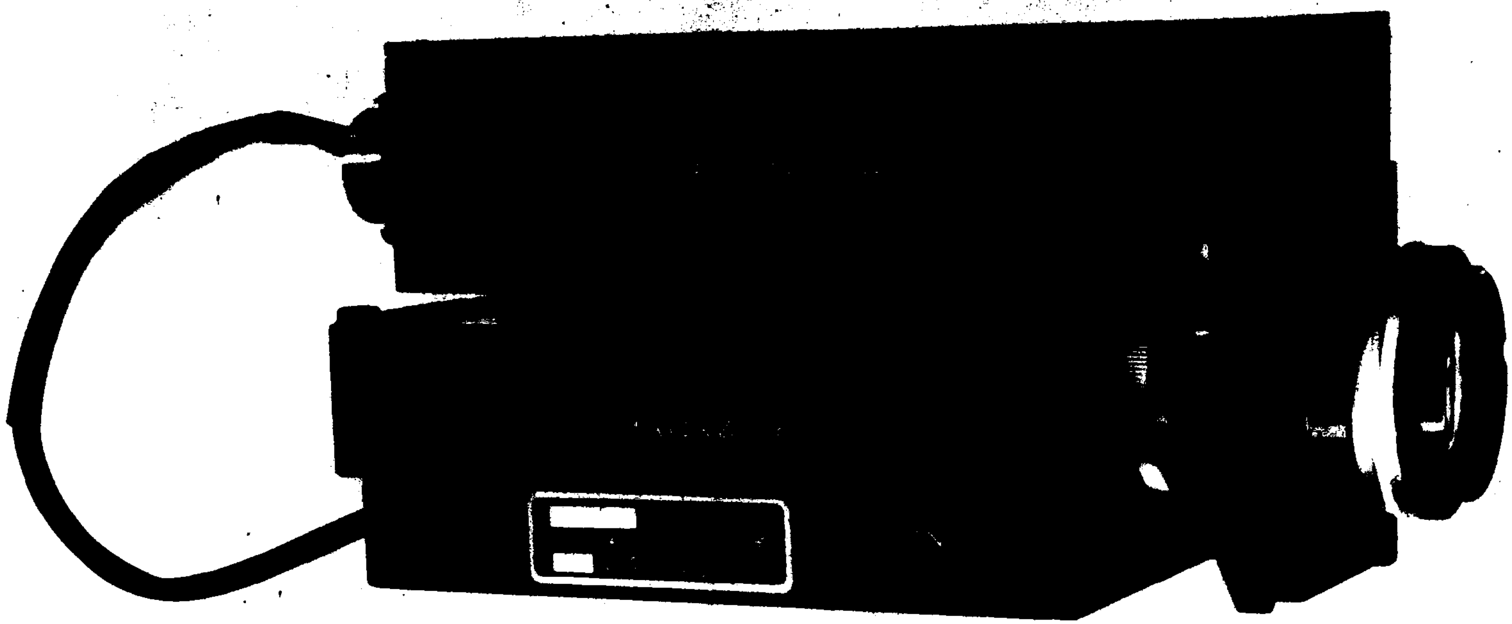


Figure 1. The complete instrument assembly, with a 65' film magazine loaded into the camera. Connectors for the time code and power are on the back (upper left) of the intervalometer housing.

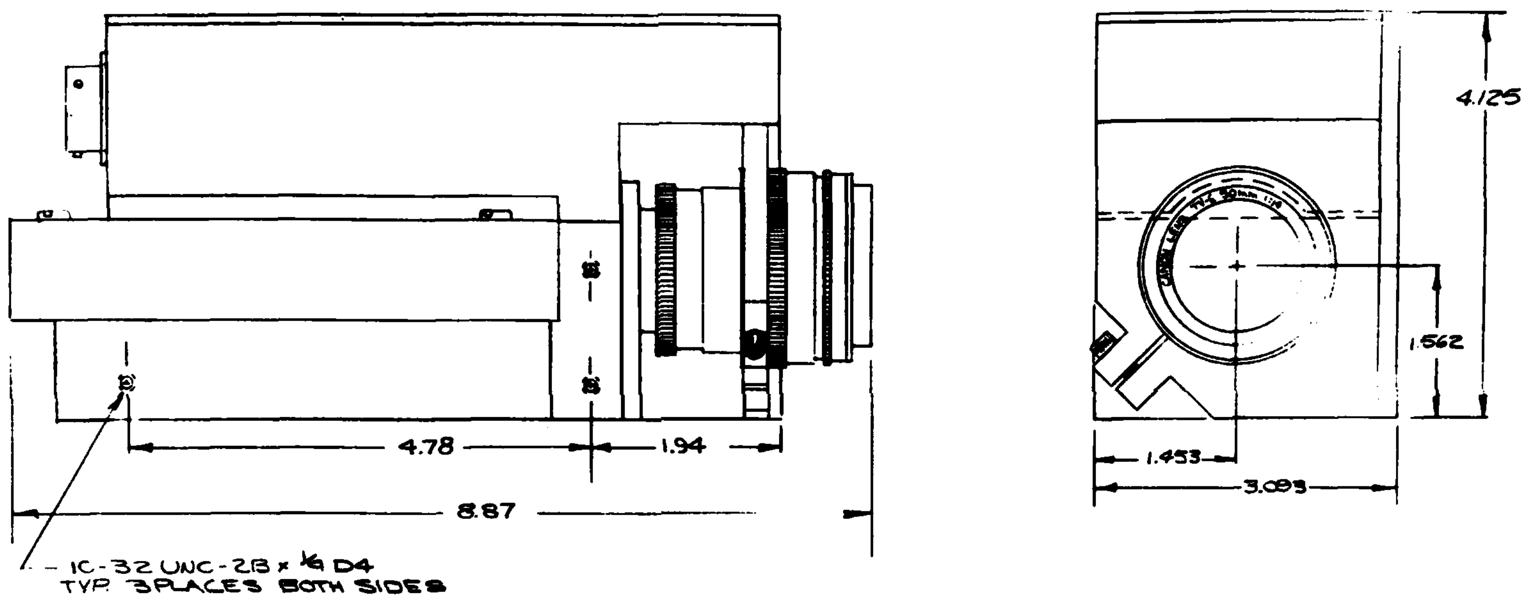


Figure 2. Outline drawing of the instrument assembly. Its weight with the film magazine and 65' of film is 2.7 kg.

Film Magazine and Film Type (pp 1 4 & 2-8)

The film magazine, which incorporates the film advance and pin registration mechanisms, holds a maximum of 65ft of film (p 1-10). This length is attained with .004 in thick, Estar-base film. The magazine can also accommodate acetate base emulsions (.007 in thick) but the capacity will be reduced to ~40ft. The film should be spooled to Eastman Kodak Specification 438, which is 16 mm wide, double-perforated stock, wound emulsion side in, onto Kodak No. 6 magazine cores. Since film wound to Spec 438 is available from Eastman Kodak only in lots of ~150 rolls of one emulsion, we routinely respool Spec 430 or Spec 449 film onto No. 6 cores if only small quantities are needed. A few emulsion types are available in Spec 438 from Photo-Sonics.

Lens

A Cannon 50 mm focal length, f/1.4 lens is the primary taking objective, which provides a field-of-view of approximately $8^{\circ} \times 14^{\circ}$. A lens support bracket gives additional mechanical stabilty and locks the focusing ring in place. Since maximum aperture is required for this experiment, the iris diaphragm has been removed to prevent accidental closing.

Time Code Display

A six digit display records which of the 12 gun modes is being used, and how many cycles-of-12 have occurred. Digits 1 and 2 indicate the mode, and digits 3 thru 6 indicate the cycle number. A decimal point separates the two sets of digits. The method for interpreting the code is explained in Section II. The display device is a light emitting diode (LED), which is imaged between the sprocket holes of the film by the optics diagrammed in Figure 3a. The LED, first surface mirror and lens are located along the bottom of the intervalometer housing, while the prism is mounted directly into the camera body. Focusing is accomplished by moving the lens and its mounting

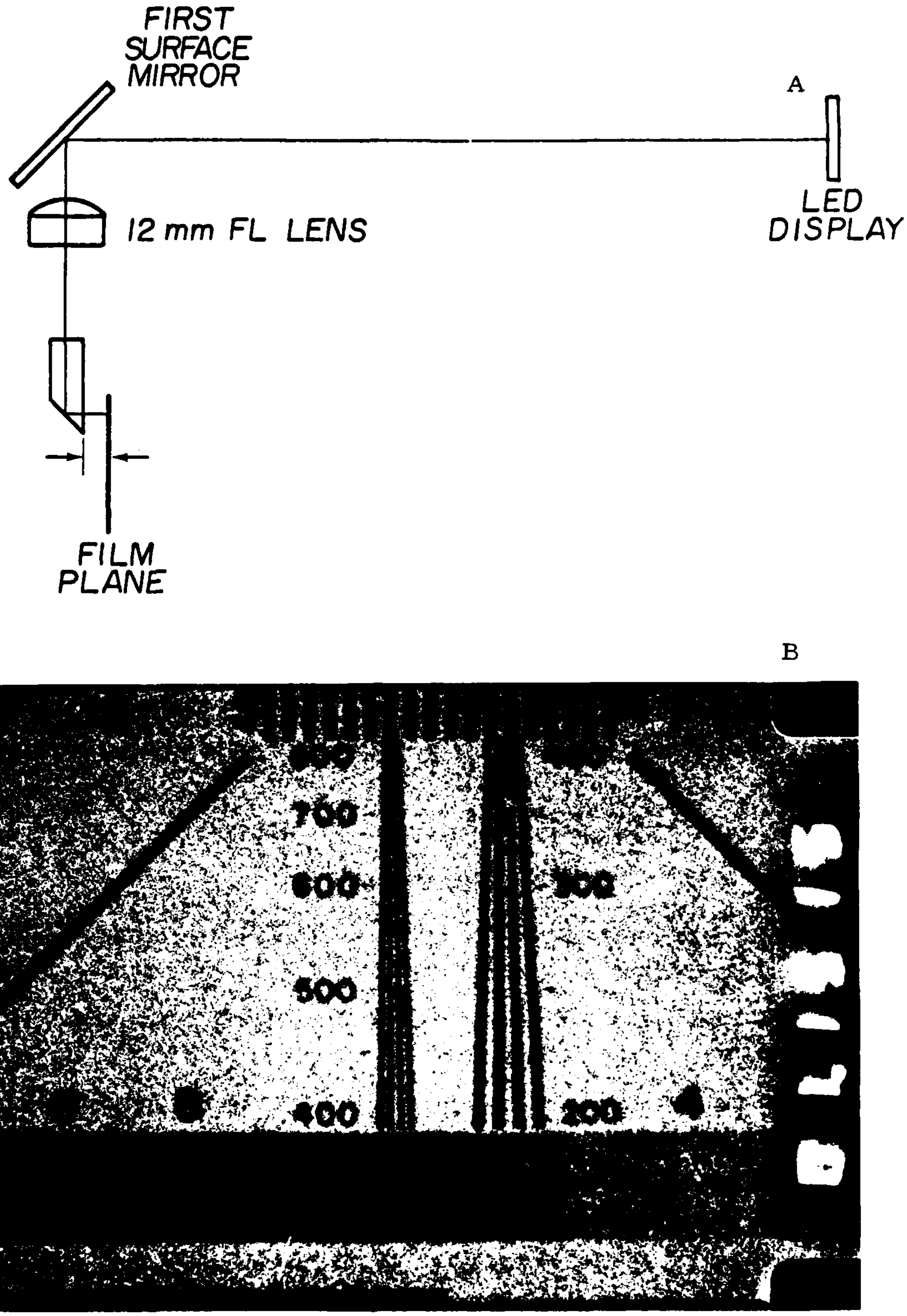


Figure 3. a) Layout of the optical system which images the time code onto the film.
b) LED display of code 01.1515, imaged between the film's sprocket holes. See Section II for interpretation of code.

ring, which is held in place by a set screw. Two reflections (one at the mirror, another internally in the prism) enable the digits to be correct left-to-right when the negative is printed (Fig 3b).

OPERATING PROCEDURES

The camera, intervalometer and display assembly is self-contained, and requires no adjustment once it is mounted on the rocket. To insure correct camera operation, the following checks should be performed prior to installation on the rocket, and before inserting the film magazine:

Time Code Display Brightness

The brightness of the digital LED display can be varied with potentiometer R21 (Fig 7b). A film test should be performed to set R21 such that the image of the digits' is easily legible. If the LED brightness is too great, light scattered from the emulsion and aperture gate will fog the data area of the film. The film type and processing procedure should be those which will be used for actual data recording.

Camera Switches

There are two rotary switches on the plate to which the film magazine is attached (p 2-7). The Overrun Control switch should be set to 0 seconds, and the Frame Rate Control switch set to PLS (pulse mode). If the rate switch is not in PLS when the camera receives run pulses, the camera will operate in cine mode for ~1/4 second - rather than pull only one frame of film - for each pulse received.

Focus and Field-of-view

When the instrument is mounted in the rocket, the boresight tool (p 1-11) should be used to ascertain that the target is positioned correctly within the field-of-view, and that it is in focus (p 2-5). It is also possible to verify that the LED display is functioning and correctly focused by pressing the RUN button located on the back of the IVN camera, and viewing the image directly in the boresight tool.

Magazine Loading (pp 2-9 to 2-11)

PhotoMetrics' field experience with the 1VN has shown that nearly all camera failures can be attributed to improper loading of film into the magazine, stray pieces of film or tape in the film drive mechanism or slippage of the film on the take-up spool. Before inserting the film supply spool, check that the footage counter is reset to 65; after film is loaded, advance it a few frames by manually turning the drive pin located on the front of the magazine and then re-open the magazine (in total darkness) to check that the film is securely attached to the take-up spool. After inserting magazine into the camera, check that the Load/Lock button, located on the back of the camera, is fully up in the Lock position (pp 2-11 & 2-12).

Electrical Checks

Before applying 28 VDC power to pin B of connector J2 (Fig 5), make certain that the polarity is correct. The input to the 1VN is not protected against reversed polarity, which will result in failure of the camera electronics.

Camera operation can be verified indirectly by monitoring the output at pin N of connector J3 through the rocket telemetry system. A 50 milli-second, 5 volt pulse is produced by the shutter rotation sensor and will be present once per shutter rotation (p 3-3). Lack of this pulse indicates that the shutter is not operating, and thus film is not being advanced.

SECTION II

THEORY OF OPERATION

OVERVIEW

The camera's intervalometer is supplied the same mode and cycle information that is provided to the electron and ion guns. This information, in a binary coded format on 12 parallel data lines, originates in an onboard programmer, which is the master sequencing device for the rocket experiments. The intervalometer itself has three functions: First, it translates the binary mode and cycle number codes into a digital format, which is then imaged onto the edge of each data frame. Second, it creates a 28 VDC, 15 ± 5 millisec pulse which energizes the 1VN's run relay (p 3-4), and thus advances the film at each mode change as explained in Section I. Lastly, it takes the 10μ sec shutter correlation pulse from the camera (p 3-3), stretches it to 50 millisec, and outputs it to one of the rocket's housekeeping telemetry channels. The functional relations of programmer, intervalometer and camera, and the timing sequence of the pulses described above are depicted in Figure 4.

INTERCONNECTIONS

The connector locations, types and pin assignments are shown in Fig 5. Primary power (28 VDC) is supplied to the intervalometer via J2, and then routed to the 1VN camera through J1 and P1, which also supply the film advance pulses to the run relay, and provide access to the shutter correlation pulse. The 12 data lines from the programmer are input to the intervalometer through connector J3. The 5 VDC input for the intervalometer logic circuits, and the stretched shutter correlation pulse output are also wired through J3. P1 is attached directly to the cable from the camera body.

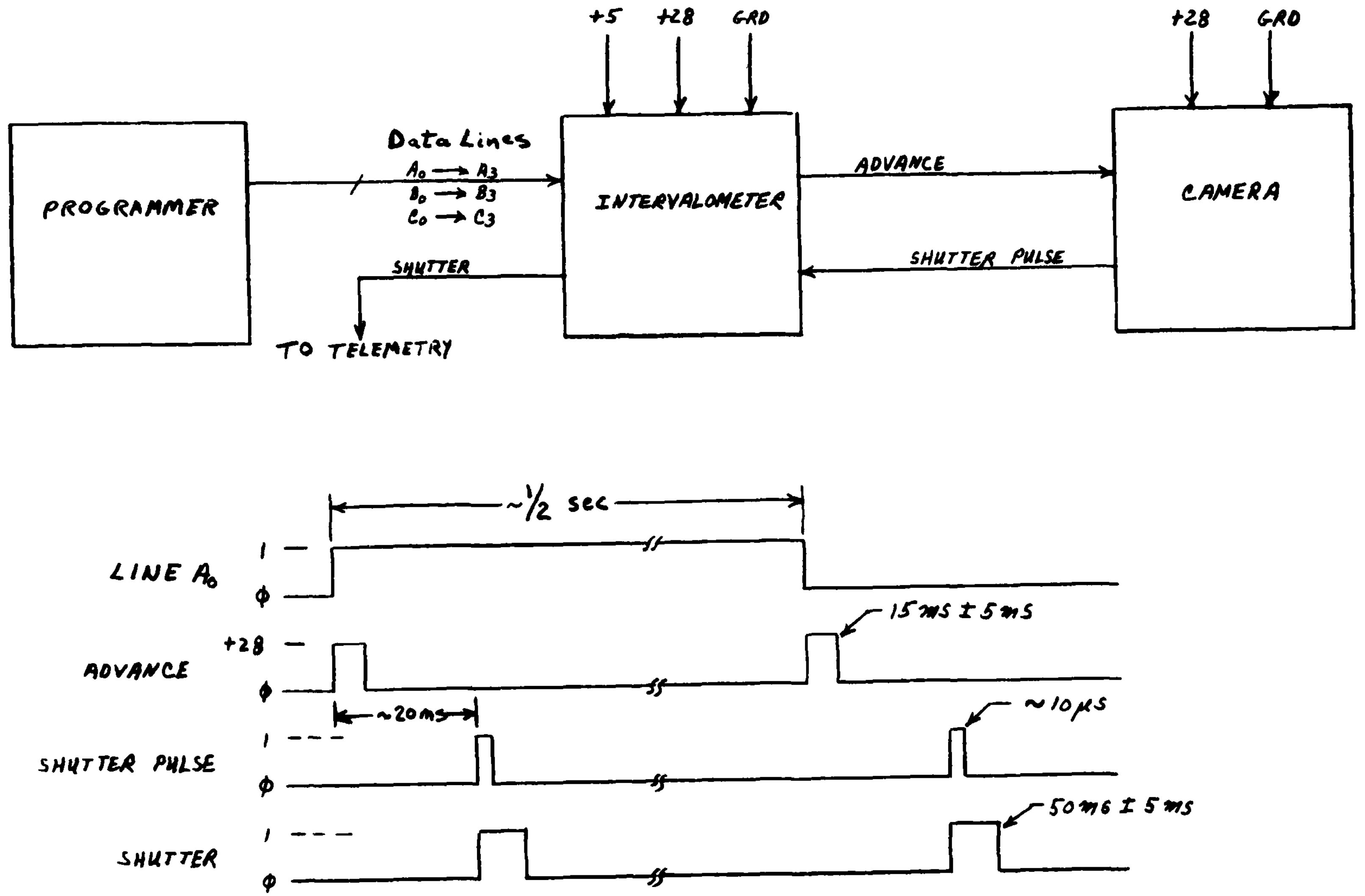


Figure 4. Functional block diagram of the instrument and rocket electronics, and relationship of camera timing and reference pulses. Mode changes occur at each rising and falling edge of the A_0 data line signal.

CONNECTOR	TYPE	PIN		FUNCTION
J1	JT02A-8-6P	1	B*	Camera advance
		2	C	Return
		3	E	Shutter correlation pulse
		4	G	Return
		5	A	+ 28 VDC
		6	-	Spare
J2	JT02A-8-3S	A		Spare
		B		+ 28 VDC
		C		Return
J3	PT02A-14-19P	A		A0 Data line
		B		A1
		C		A2
		D		A3
		E		B0
		F		B1
		G		B2
		H		B3
		J		C0
		K		C1
		L		C2
		M		C3
		N		Telemetry pulse out
		P		Spare
		R		Spare
		S		Spare
		T		Return
		U		Return
		V		+ 5 VDC

*These letters refer to to original connector type PT 06-12-10 P, replaced with JT 06-8-6S (SR). Refer to schematic 74-102, page 3-10 of 1 VN camera manual.

Figure 5. Connector pin assignments for input and output functions. The photograph shows the locations of the connectors on the back of the intervalometer housing.

TIME CODE DISPLAY

When the camera intervalometer circuit receives a SHUTTER PULSE from the camera, it initiates a timing cycle which sequentially illuminates the six digits of the light-emitting diode display. The information displayed by the LED's is a function of the 12 data lines from the programmer (A_o to A_3, B_o to B_3 and C_o to C_3) and is constrained as follows:

	Digit #	Allowed Display
Mode	1	0 → 1
Digits	2	0 → 5
	3	0 → 1
Cycle	4	0 → 7
Digits	5	0 → 1
	6	0 → 7

6-Digit Display
TIL360

Digit# → 1 2 . 3 4 5 6

↑

Decimal
Point

Thus constrained, the intervalometer can display a maximum of 12 modes and 256 cycles by using the following code: The first and second digits are a base 6 number; this number plus 1 equals the mode. The third and fourth digits, and the fifth and sixth digits are two pairs of base 8 (octal) numbers; the left-hand number times 16, plus the right-hand number, plus 1 equals the cycle number. For example, 13.1207 would be translated as follows:

$$\text{Mode} = 13_6 + 1 = 10$$

$$\text{Cycle} = (12_8 \times 16) + 07_8 + 1 = 168$$

This code – rather than a decimal code – was chosen because it permitted simplification of the electronics design.

DETAILED CIRCUIT DESCRIPTION

The following subsection provides a detailed explanation of the operation of the electronic circuits of the intervalometer. The component labels, device designations and signal nomenclature referred

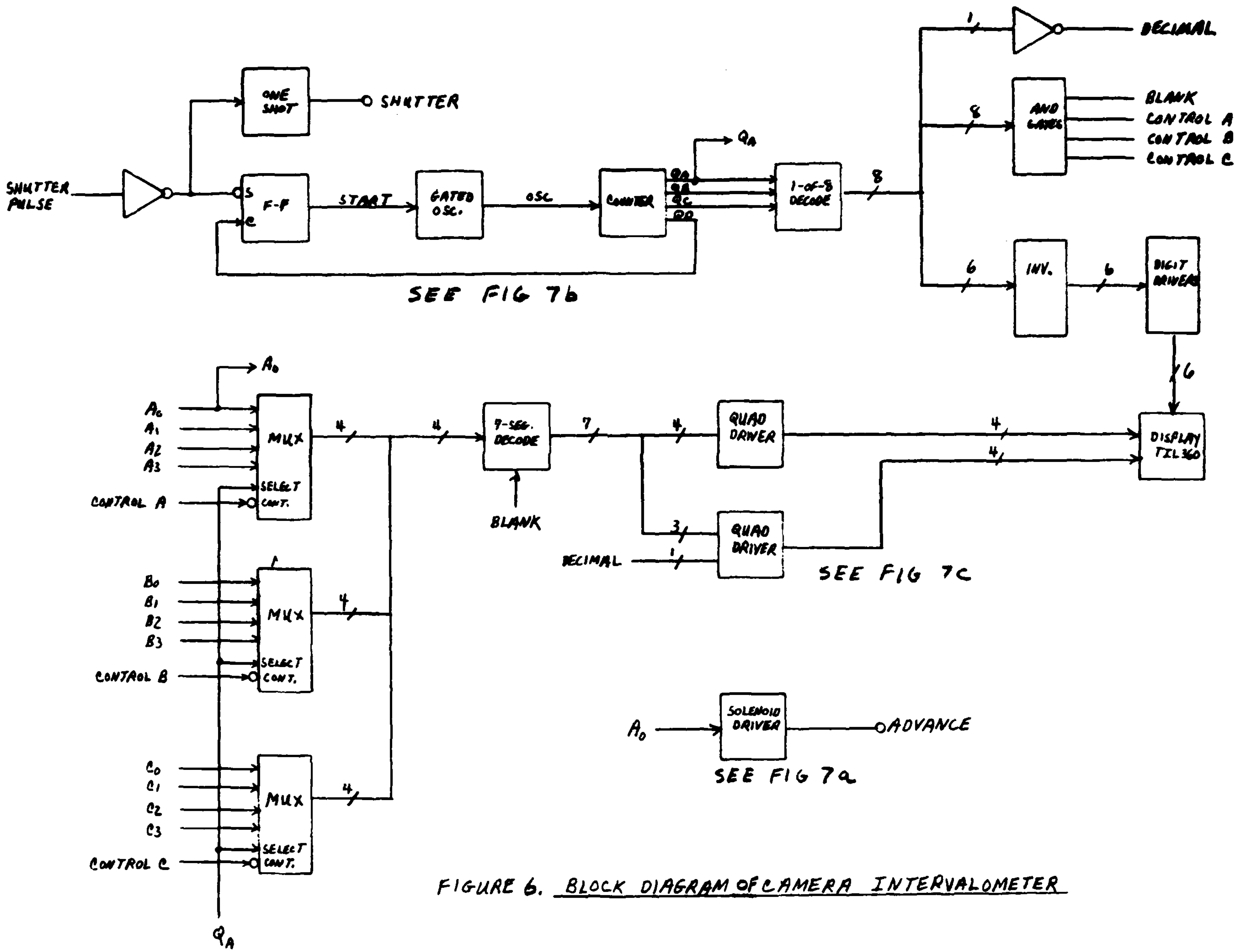


FIGURE 6. BLOCK DIAGRAM OF CAMERA INTERVALOMETER

to are those used in the schematics and diagrams presented as Fig's 6 thru 9. For completeness, a schematic of a test circuit is included (Fig 10) which enables the intervalometer and time code display to be checked out independently of the rocket's programmer. Component locations are indicated on the photograph of the intervalometer circuit board and time code housing interior (Fig 11).

Solenoid Driver (Refer to Fig 7a)

Each low-to-high and high-to-low transition of the A_o data line generates a film ADVANCE pulse that is transmitted to the camera. Assume that A_o is low (logic 0) and that $\overline{Q}$ (pin 6 of the 74LS74 F-F) is high (logic 1). The output of the XOR (exclusive OR) gate, $\overline{TRIG}$, will then be high. When A_o switches from low-to-high, $\overline{TRIG}$ will go low, thereby triggering the 555 one-shot. The leading edge transition of the one-shot output (called ADVANCE) clocks the flip-flop causing it to toggle once, forcing $\overline{Q}$ low. $\overline{Q}$ going low causes $\overline{TRIG}$ to switch back to the high state since the XOR gate inputs are now of opposite polarity, namely, A_o = high and $\overline{Q}$ = low.

The ADVANCE pulse also is used to turn transistor Q_1 on, which turns transistor Q_2 on, sending a +28 volt, 15 ± 5 ms pulse to the camera. When the one-shot times out, Q_1 and Q_2 are turned off, terminating the film ADVANCE pulse output.

When A_o again changes state, this time from high-to-low, another $\overline{TRIG}$ pulse is generated via the same mechanism as above, resulting in another ADVANCE pulse. In this case, however, the XOR gate inputs will be A_o = low and $\overline{Q}$ = high. The timing relationships for this process are diagrammed in Fig 8.

The second one-shot (Fig 7a) stretches the shutter pulse received from the camera. Each high-to-low transition of $\overline{\text{SHUTTER PULSE}}$ generates a TTL level, 50 ms ± 5 ms pulse called SHUTTER which is made available to the telemetry system.

<u>Timing Cycle</u> (Refer to Fig's 7b, 7c and Fig 9)

The SHUTTER PULSE signal from the camera is inverted by E3 (1/6 54LS04) and sets the START flip-flop (B8-pin 9). START going high enables the 555 gated oscillator (B7) and the 54LS161 counter (B5). Oscillator pulses are then counted by the counter. The 3 least significant counter outputs (Q_A, Q_B, Q_c) are decoded into a 1-of-8 selection by the 54LS138 1-of-8 decoder (B6). Decoded counter outputs $\overline{2}$ to $\overline{7}$ are inverted by the 54S04 (A5) to drive the 75492 hex digit driver (B4), which in turn sequentially drives the six character-select lines of the TIL360 display device.

Decoded counter outputs $\overline{0}$ to $\overline{7}$ are logically combined at the 54LS08 (B3) to form four mutually exclusive active-low signals called BLANK, CONTROL A, CONTROL B, and CONTROL C (see timing diagram, Figure #9). Decoded output $\overline{3}$ is inverted by E3 and used as the decimal point control line to the 75491 driver (A3). When $\overline{0}$ or $\overline{1}$ is low, BLANK is low which inhibits the 54LS48 7-segment decoder (B2) outputs, forcing them all low, preventing illumination of the display. When both $\overline{0}$ and $\overline{1}$ are high, BLANK is high and the 54LS48 outputs are enabled, allowing the 75491 drivers (A3, A4), when selected, to drive the gment inputs of the display through current limiting resistors R_4 to R_8 and R_{11} to R_{13}. Display brightness is controlled by varying the oscillator frequency via 20 kΩ trimpot.

The CONTROL A/B/C signals select which of the three 54LS257A multiplexes (C_1 to C_3) is to be used to transfer data to the 54LS48 7-segment decoder (B2). The multiplexer control line input (pin 15) must be low to enable the multiplexer outputs. When a multiplexer control line input is high, that multiplexer's outputs are in a high-impedance (off) state. When a multiplexer has been selected by bringing its control line low, the Q_A output of the 54LS161 counter (B5) determines the selection of the A or B inputs. With Q_A low, the A set of inputs is selected. When Q_A is high, the B set of inputs is selected.

The table below shows the state of the multiplexer output bus for the various input conditions

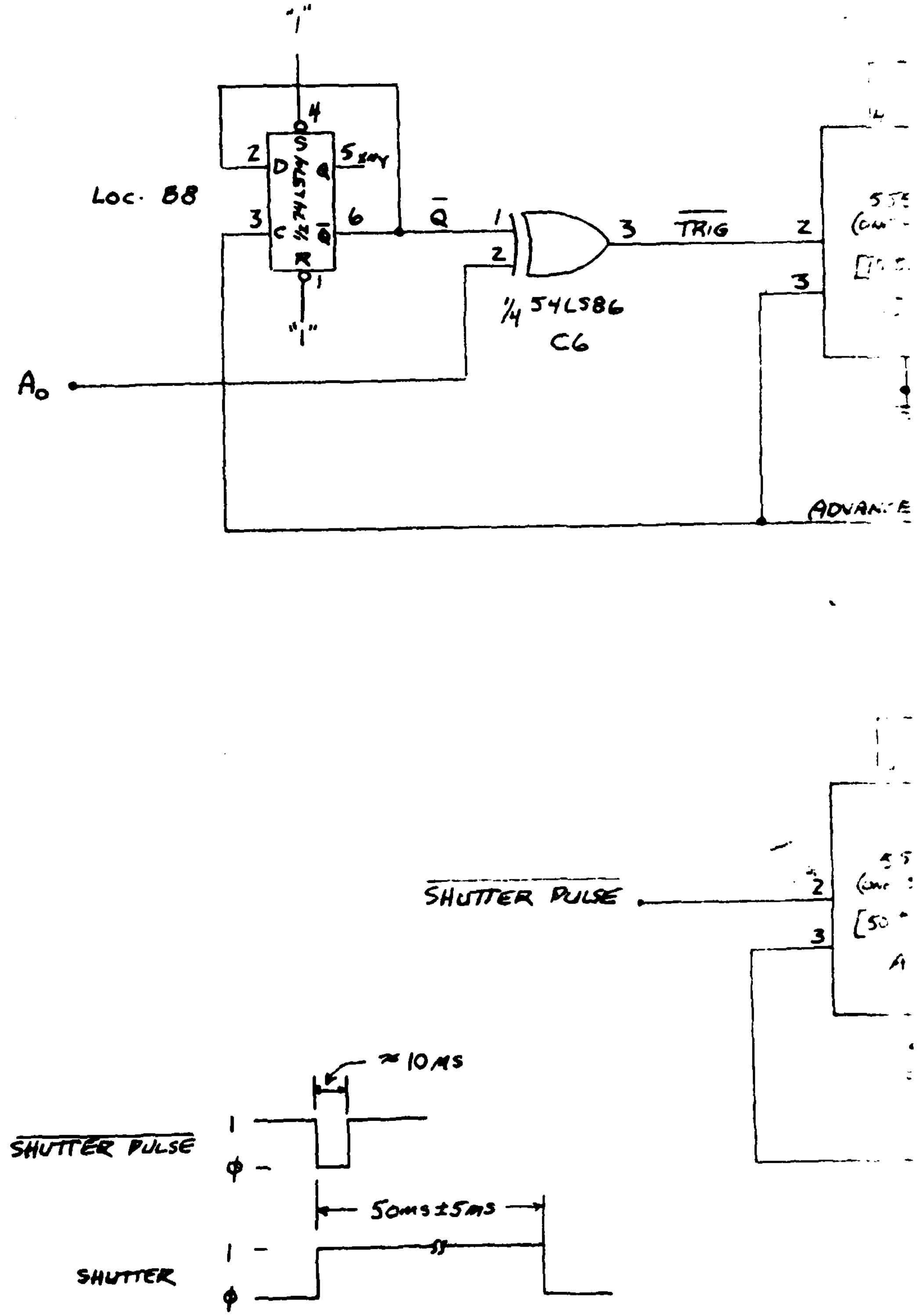
Multiplexer Inputs							
Control			Select	Multiplexer Output Bus			
C	B	A	Q_A	Pin 4	Pin 7	Pin 9	Pin 12
1	1	1	-	(High - Impedance)			
1	1	0	0	A_3	0	0	0
1	1	0	1	A_0	A_1	A_2	0
1	0	1	0	B_3	0	0	0
1	C	1	1	B_0	B_1	B_2	0
0	1	1	0	C_3	0	0	0
0	1	1	1	C_0	C_1	C_2	0

0 = logic 0

1 = logic 1

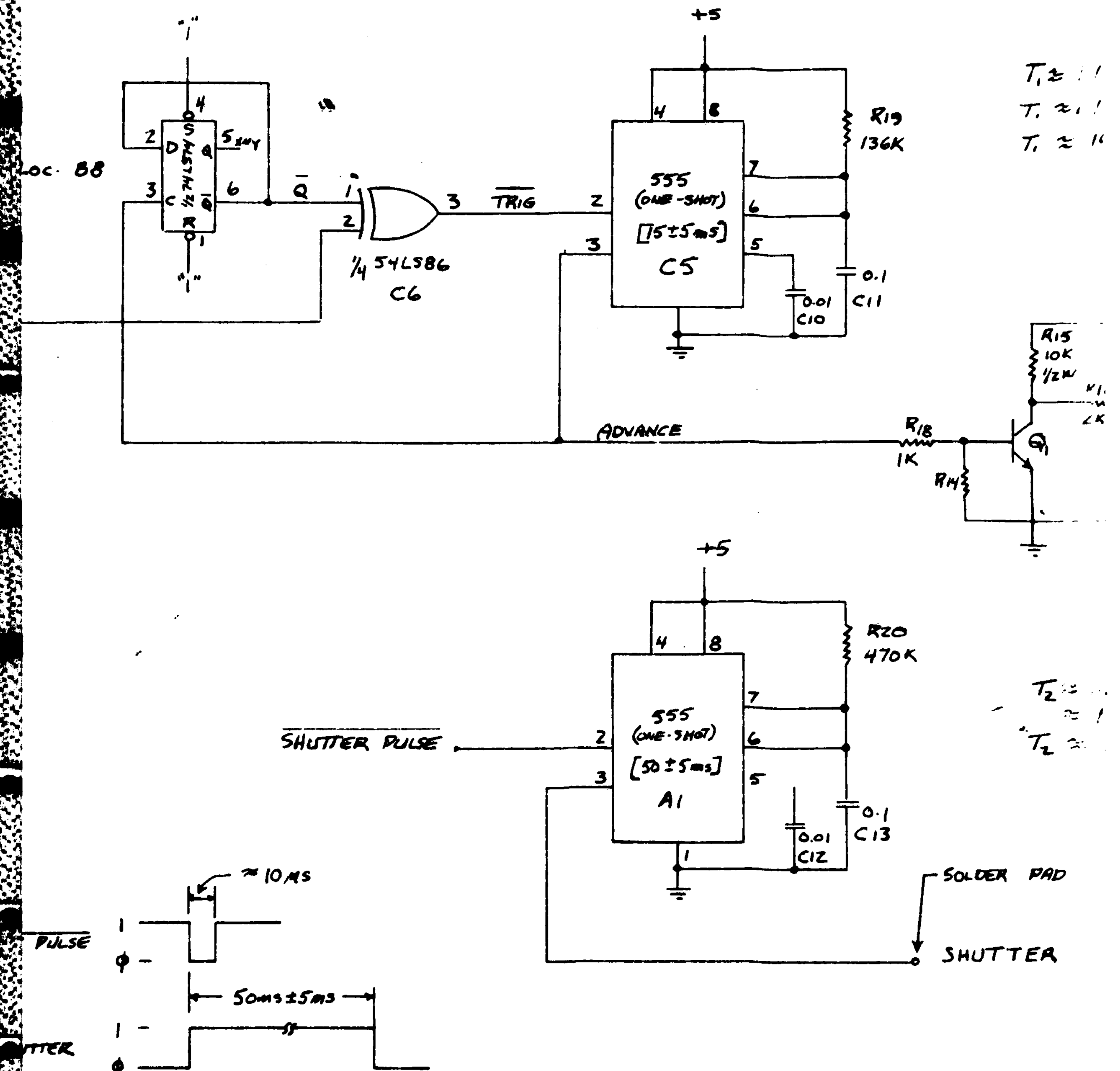
A_i, B_i, C_i = respective max input (i = 0, 1, 2, 3)

The most significant bit Q_D of the 54LS161 counter (B5) is used to reset the START flip-flop. When Q_D goes high, the START signal is clocked low, resetting the counter (B5) and the gates oscillator (B7), thereby terminating the timing cycle.



"1"
Loc. B8
½ 74LS74
D
S
Q
C
R
"1"
Q̄
TRIG
¼ 54LS86
C6
A0
SHUTTER PULSE
≈10MS
SHUTTER PULSE
50ms±5ms
SHUTTER

1



"1"
54LS74
LOC. 88
$\overline{Q}$
1/4 54LS86
C6
3
$\overline{TRIG}$
+5
R19
136K
555
(ONE-SHOT)
[15±5ms]
C5
0.01
C10
0.1
C11
R15
10K
1/2W
ADVANCE
R18
1K
R14
Q1
+5
R20
470K
555
(ONE-SHOT)
[50±5ms]
A1
0.01
C12
0.1
C13
$\overline{SHUTTER\ PULSE}$
SOLDER PAD
SHUTTER
≈ 10MS
PULSE
50ms±5ms
TTER

2

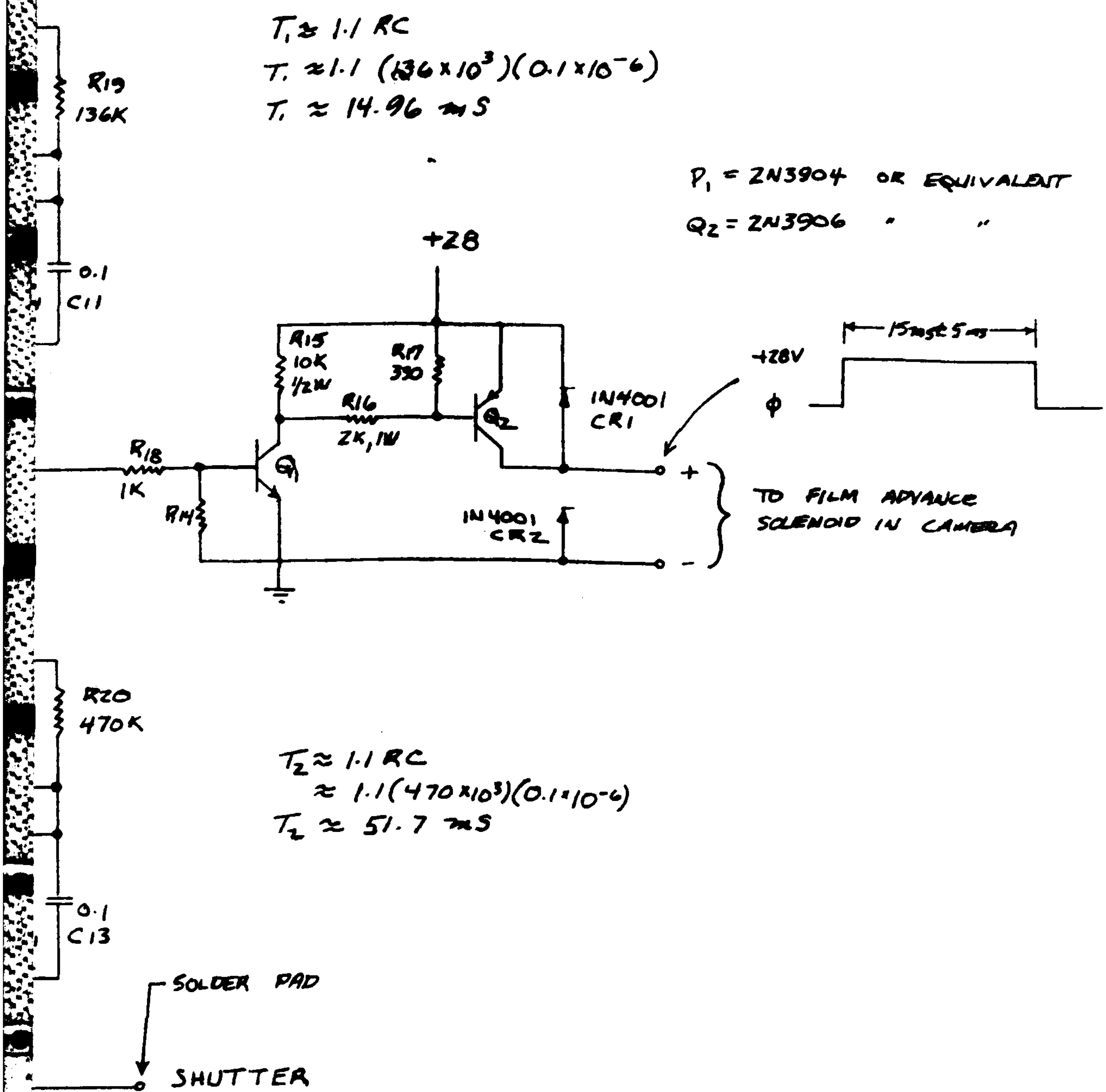
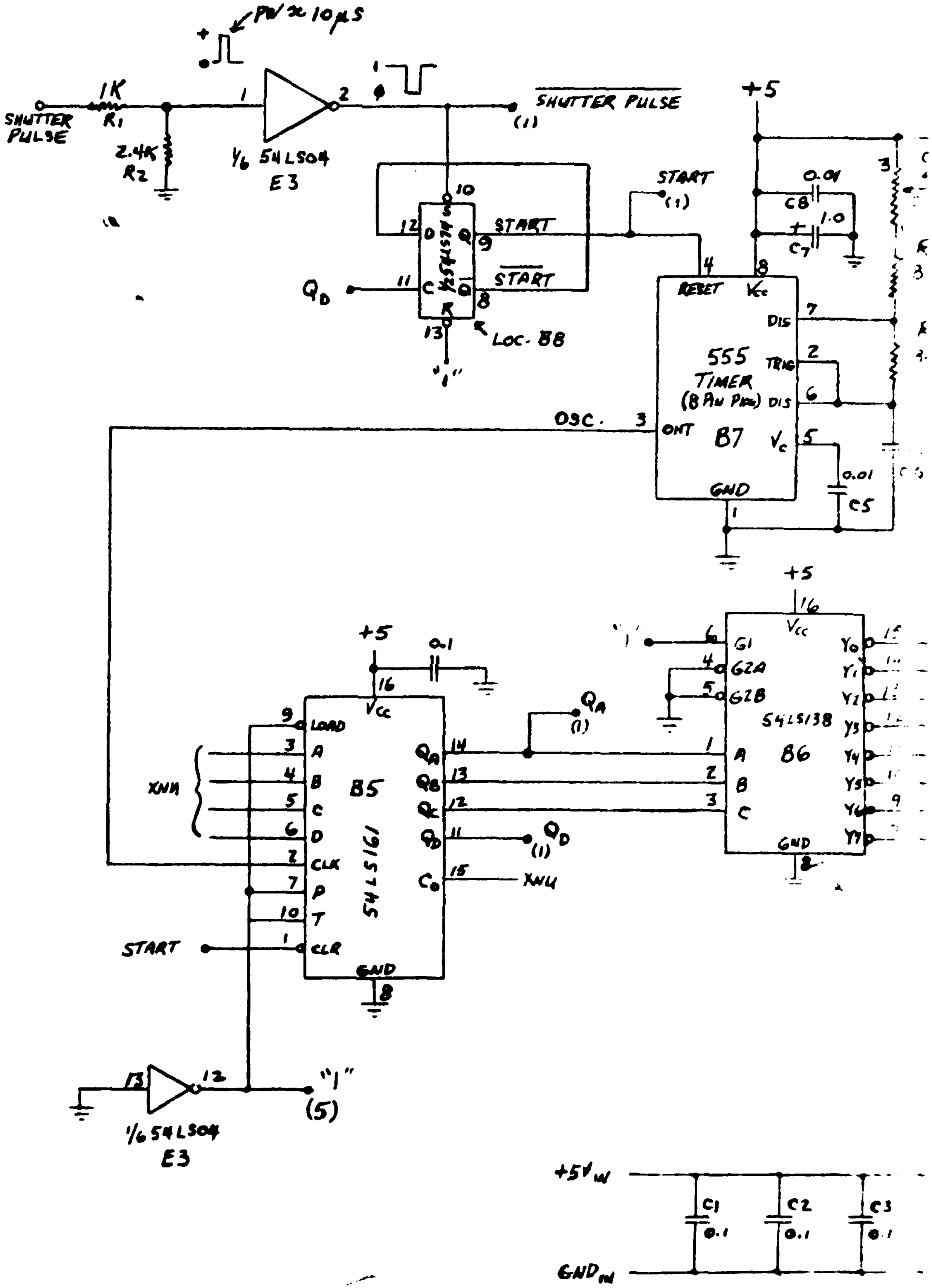
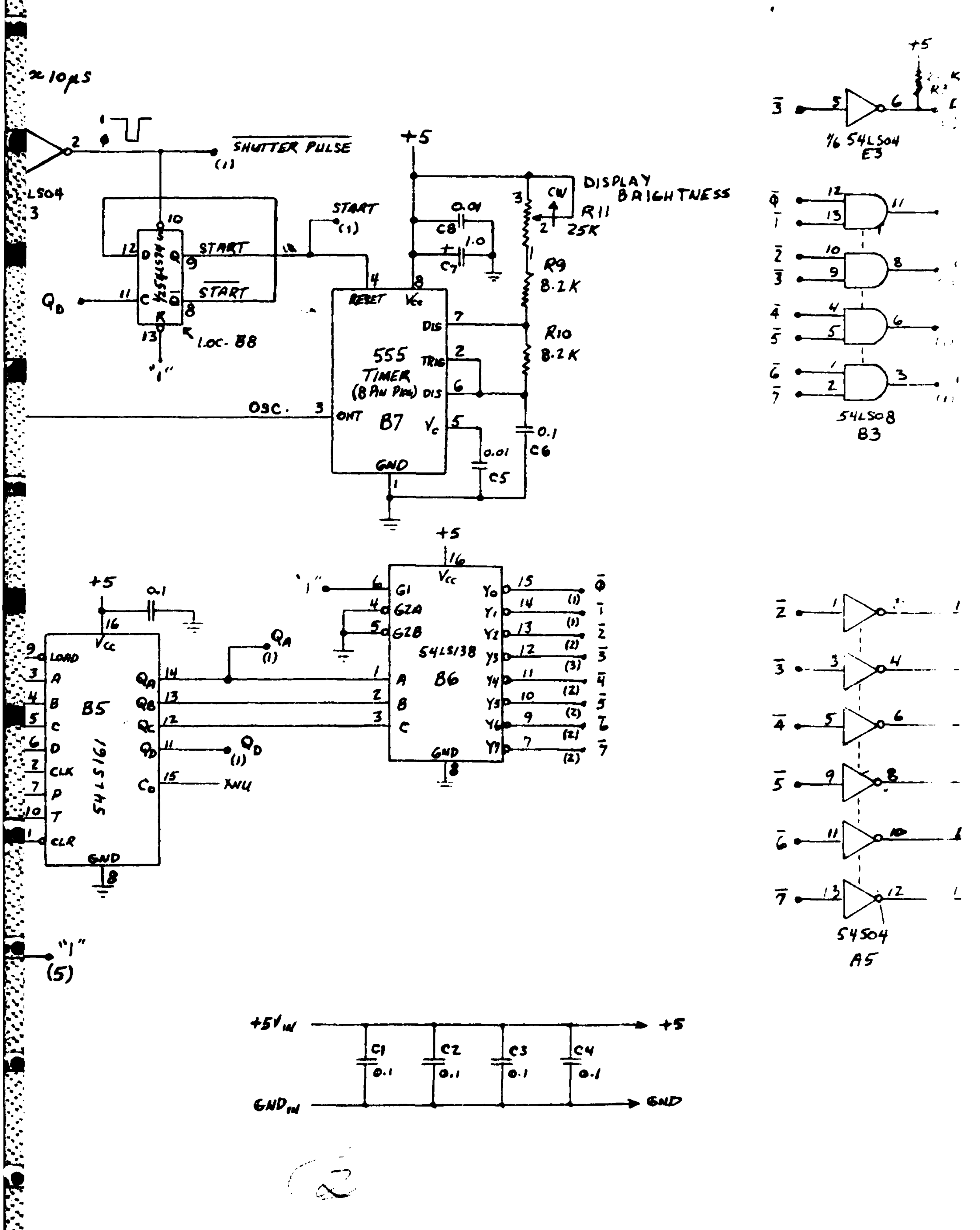


FIGURE 7a - CAMERA INTERVALOMETER SOLENOID DRIVER


PW ≈ 10µS
SHUTTER PULSE
1K
R1
2.4K
R2
1/6 54LS04
E3
SHUTTER PULSE
(1)
+5
START
(1)
0.01
C8
1.0
C7
D
Q
START
C
Q
START
R
Loc. B8
"1"
Q_D
RESET
Vcc
DIS
555
TIMER
(8 Pin Pkg)
TRIG
DIS
OSC.
OUT
B7
Vc
0.01
C5
GND
+5
Vcc
G1
G2A
G2B
54LS138
B6
A
B
C
GND
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
+5
0.1
Vcc
LOAD
A
B
C
D
CLK
P
T
CLR
B5
54LS161
QA
QB
QC
QD
C0
GND
XNN
Q_A
(1)
Q_D
(1)
XN4
START
1/6 54LS04
E3
"1"
(5)
+5V_IN
GND_IN
C1
0.1
C2
0.1
C3
0.1



≈ 10 μS
SHUTTER PULSE
LS04
START
½ 54LS74
Loc. B8
DISPLAY BRIGHTNESS
R11 25K
CW
C8 0.01
C7 1.0
R9 8.2K
R10 8.2K
RESET
V_{cc}
DIS
TRIG
555 TIMER (8 Pin Pkg)
B7
OSC.
OUT
V_c
GND
0.1 C6
0.01 C5
+5
54LS161
B5
LOAD
CLR
CLK
XNU
54LS138
B6
G1
G2A
G2B
1/6 54LS04 E3
54LS08 B3
54S04 A5
"1" (5)
+5V IN
GND IN
C1 0.1
C2 0.1
C3 0.1
C4 0.1
+5
GND

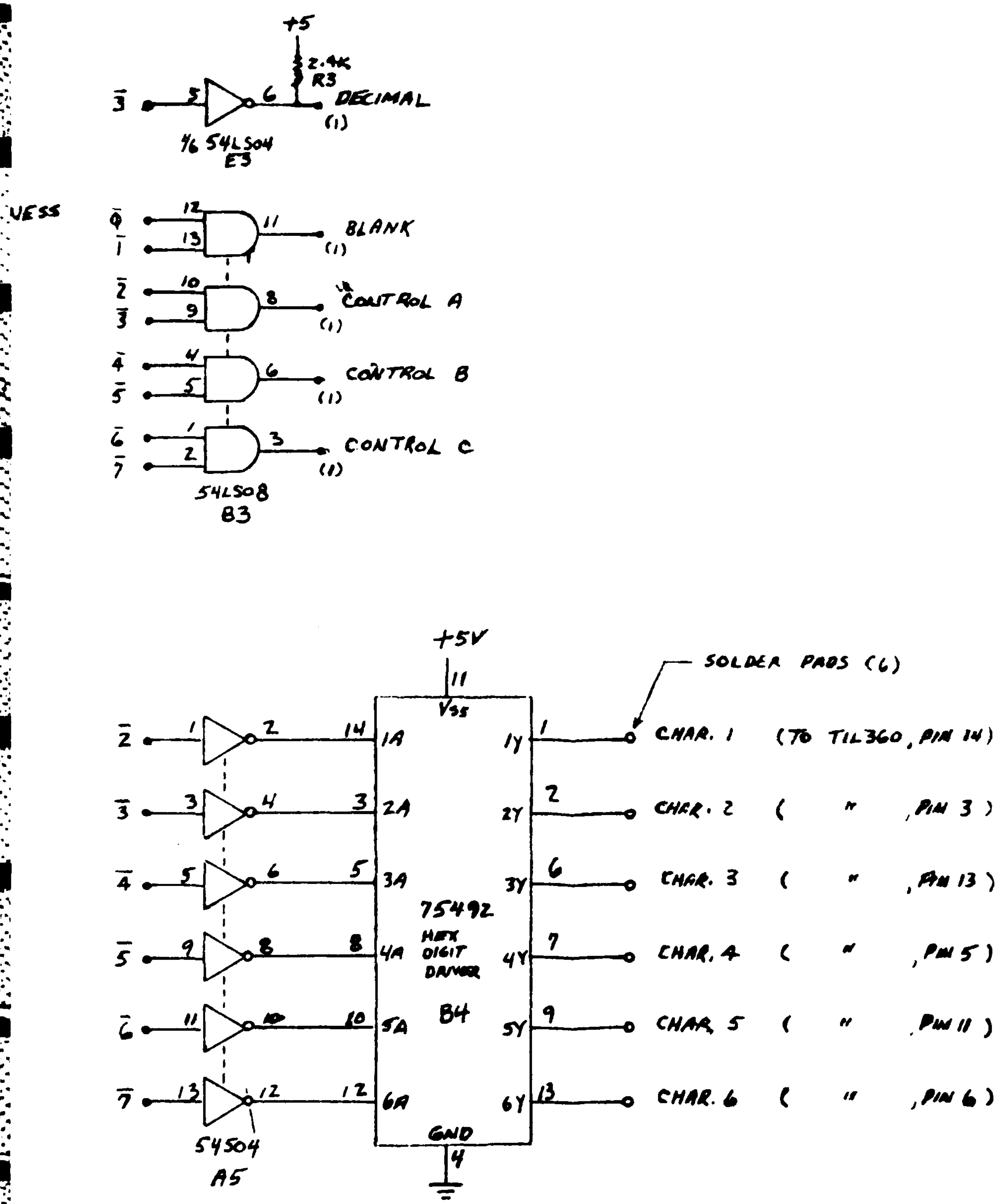
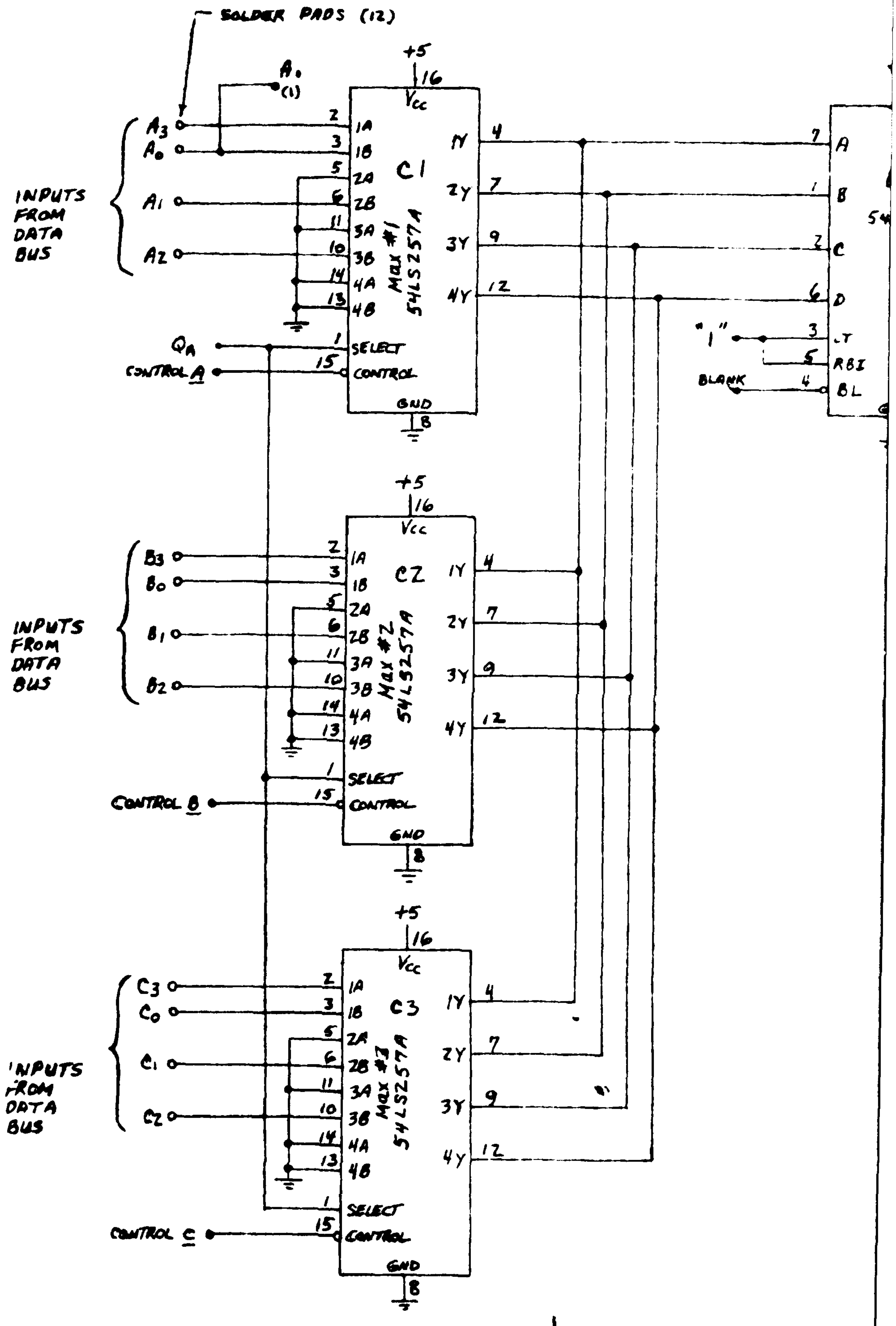


FIGURE 7b - CAMERA INTERVALOMETER


SOLDER PADS (12)
INPUTS FROM DATA BUS
C1
Mux #1 54LS257A
C2
Mux #2 54LS257A
C3
Mux #3 54LS257A
Q_A
CONTROL A
CONTROL B
CONTROL C
SELECT
CONTROL
GND
Vcc
+5
BLANK
RBI
BL

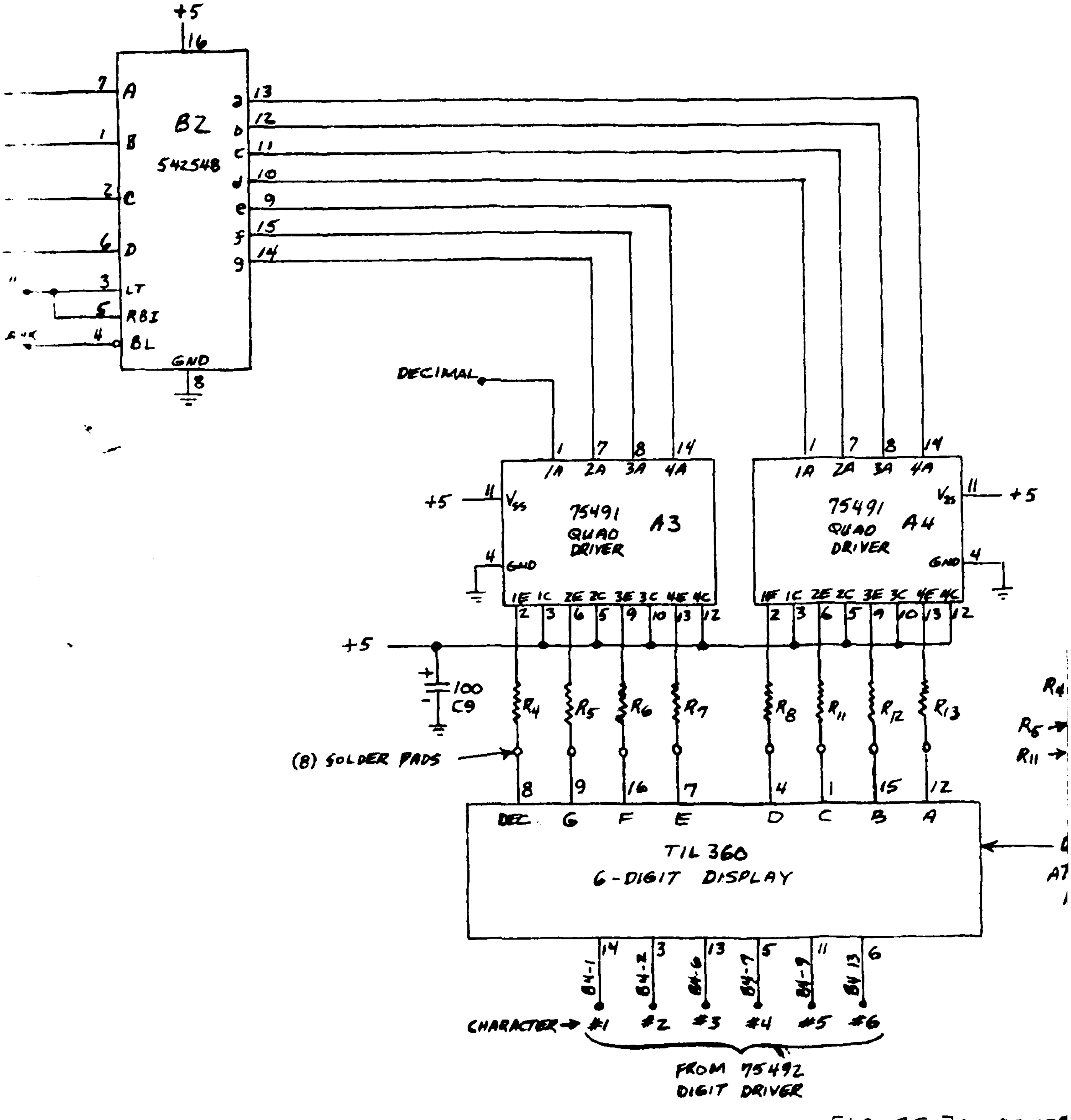


FIGURE 7C - CAMER

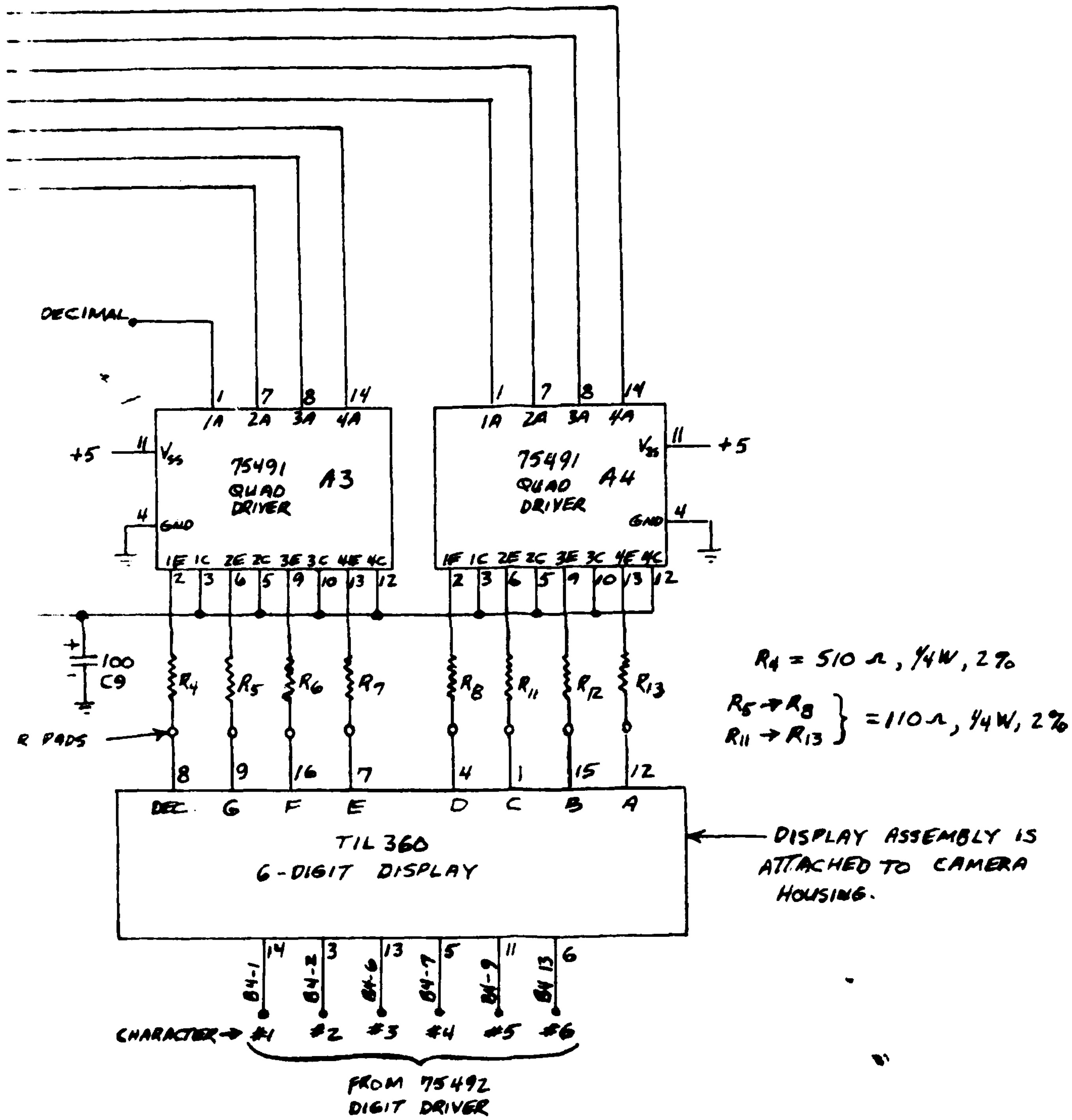
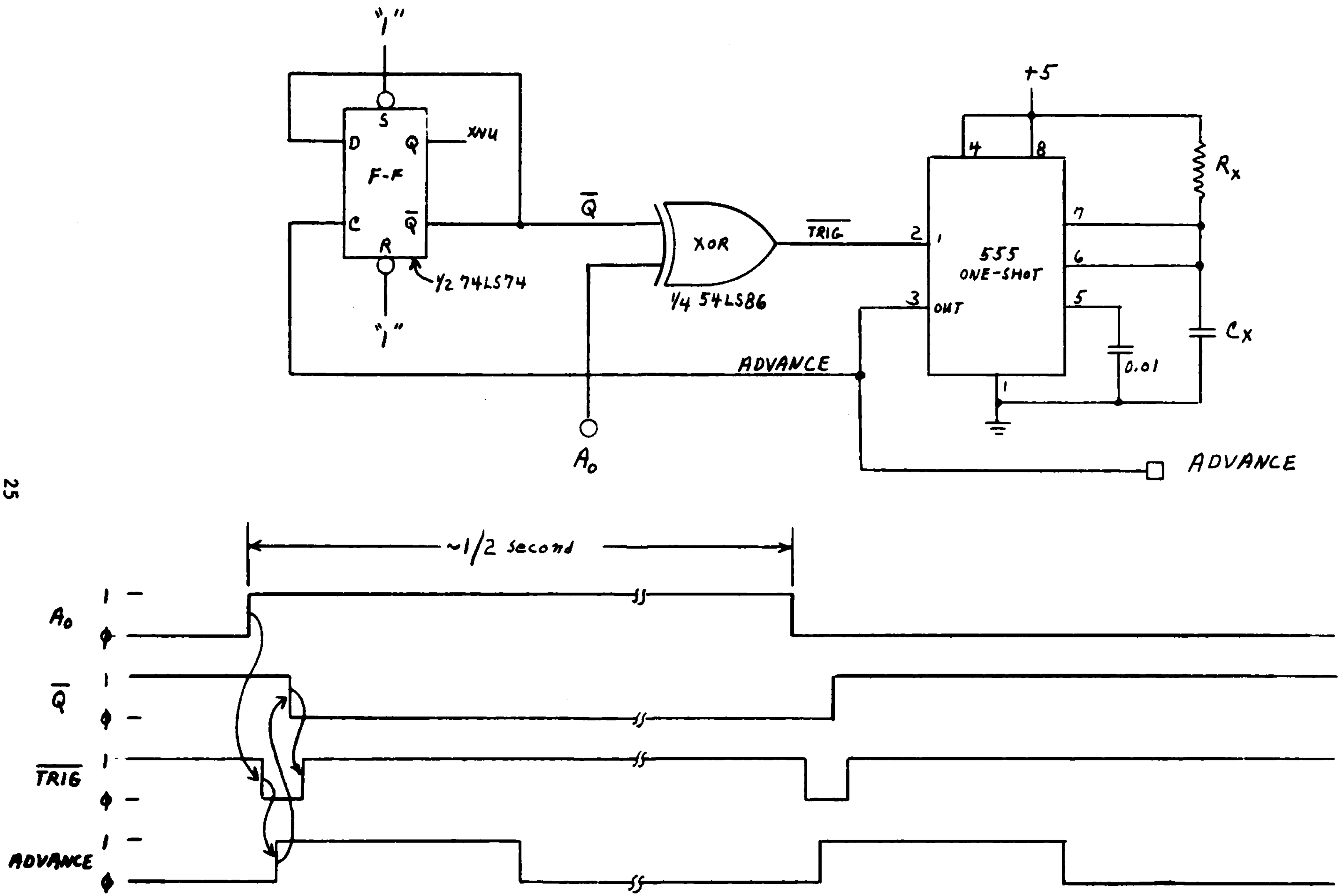


FIGURE 7C - CAMERA INTERVALOMETER



NOTE - TIMING DIAGRAM IS NOT TO SCALE.

FIGURE 8 — SOLENOID DRIVER CIRCUIT

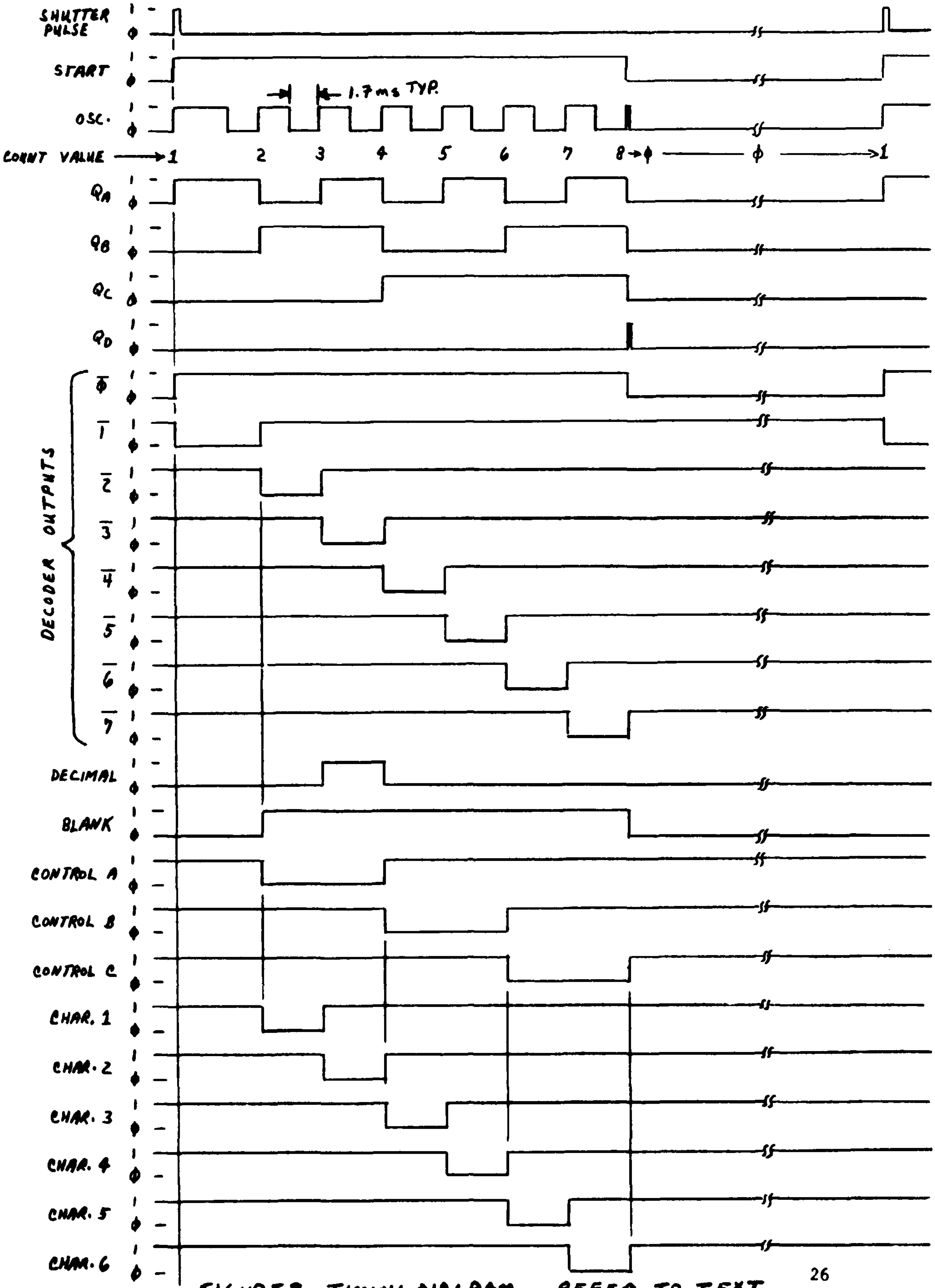
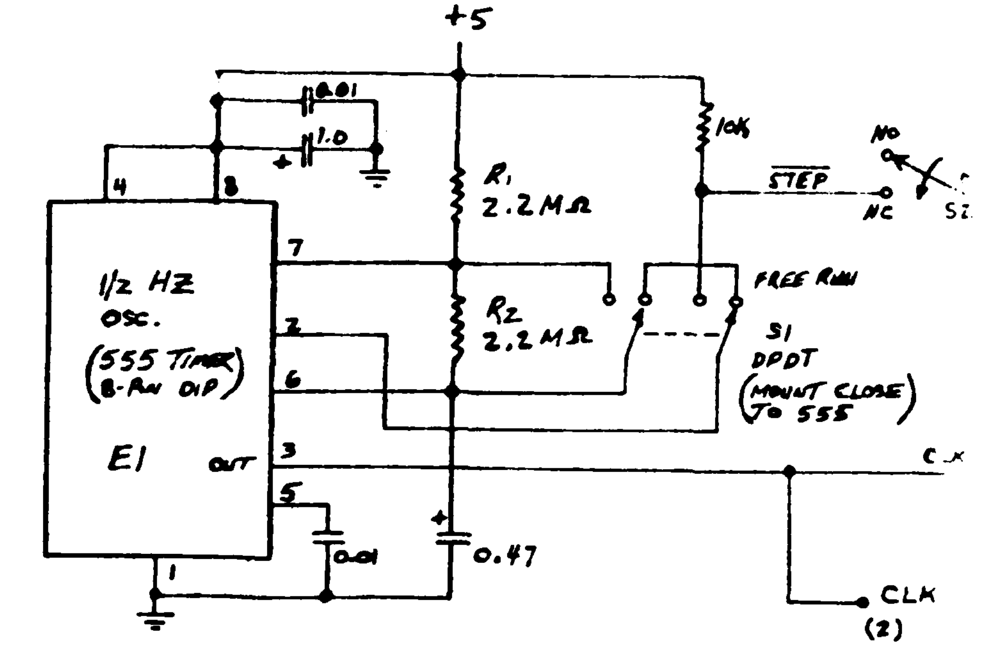
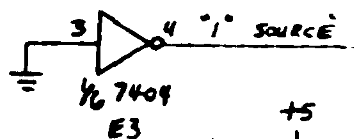
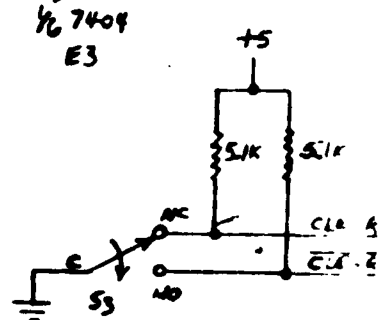


FIGURE 9. TIMING DIAGRAM - REFER TO TEXT







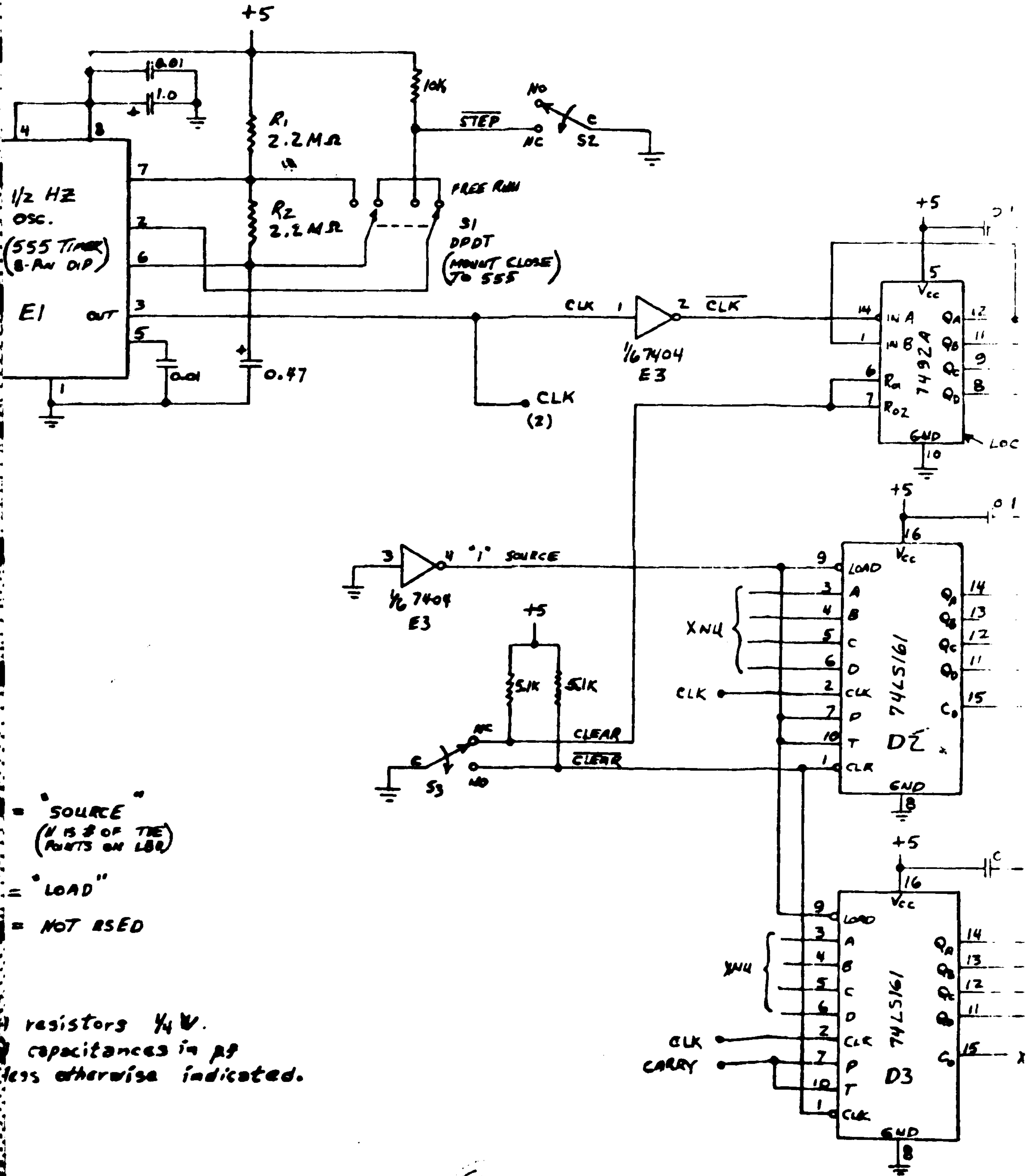
LEGEND

CLK (N) = "SOURCE" (N IS # OF THE POINTS ON LBB)

CLK = "LOAD"

XNU = NOT USED

NOTES: 1. All resistors 1/4 W.
2. All capacitances in μf unless otherwise indicated.



= "SOURCE" (N is # of the points on LBR)

= "LOAD"

= NOT USED

All resistors 1/4 W.
All capacitances in µf unless otherwise indicated.

S1 = DPDT SW. (MAINTAIN-MAINTAIN)
S2 = SPDT SW. (MOMENTARY)
S3 = " " "
S4 = SPDT " (MAINTAIN-MAINTAIN)

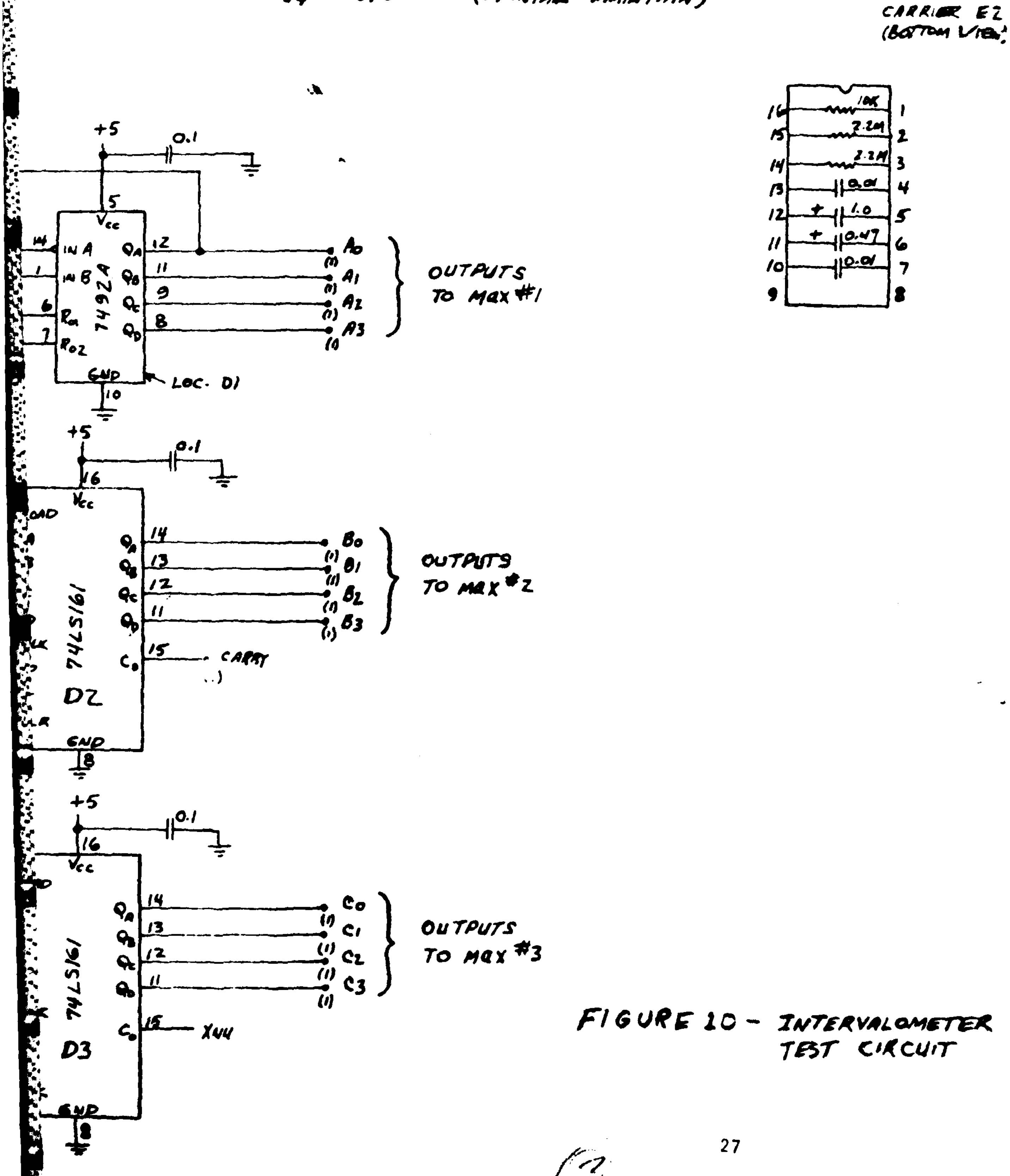


FIGURE 10 - INTERVALOMETER TEST CIRCUIT

Figure 11. Component layout on the intervalometer circuit board, and interior view of the intervalometer housing.

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